Final Report: Modeling the Volcanic Source at Long Valley, CA, Using a Genetic Algorithm Technique

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A. SUMMARY.

In this project, we attempted to model the deformation pattern due to the magmatic source at Long Valley caldera using a real-value coded genetic algorithm (GA) inversion similar to that found in Michalewicz, 1992.

The project has been both successful and rewarding. The genetic algorithm, coded in the C programming language, performs stable inversions over repeated trials, with varying initial and boundary conditions. The original model used a GA in which the geophysical information was coded into the fitness function through the computation of surface displacements for a Mogi point source in an elastic half-space. The program was designed to invert for a spherical magmatic source - its depth, horizontal location and volume - using the known surface deformations. It also included the capability of inverting for multiple sources.

As of August, 1999, the program has been revised to model a more complicated source pattern, including both elliptical sources and fault sources. The elliptical model inverts for the horizontal location, the depth, and the major and minor axes of a prolate ellipsoid, as well as its volume, and both its orientation and dip angles. The fault model inverts for the fault displacement, knowing the type and location of existing fault structures. Again, the program can invert for both multiple sources of a given type as well as a mixture of the source types themselves.

After prolonged testing of parameter ranges and inversion stability on synthetic data, the GA was employed to invert actual data from Long Valley for both spherical and elliptical sources. While the model has the capability of inverting GPS measurements, expansion line readings and simple leveling or uplift data, available data included two-color geodolite measurements at very high accuracy, leveling circuits at better than average precision and laser altimeter data with substantial coverage and lower accuracy. All three types were incorporated into a time-dependent inversion in an initial attempt to locate the sources below the dome

throughout the early to mid-1990s. Shown on the next few pages are the location plans for that data and the inversion results for both a two spherical source model and a two ellipsoid source model using laser altimeter and geodolite measurements.

The GA was modified to include options for multipoint crossover and windowing. These options have been tested on different inversion problems to determine their applicability for different fitness landscapes with varying standard deviations on the parameters themselves. In addition, a combination of research and testing has led to better recommendations for appropriate mutation rates. A thorough error analysis on the GA results for different source models also was completed this year. In addition, the model has been modified to include multipoint crossover and proportional mutation, both of which proved to be more efficient for searching the large parameter space associated with the ellipsoidal models.

In a 1998 collaboration with other CU researchers, the genetic algorithm developed for this project was employed in a waveform inversion for the crustal structure of the western U.S., and the results were published in BSSA, 1999 (see below).

Substantial work was done in the last year in understanding the interactions between the various ellipsoidal parameters, specifically volume, depth and length of semimajor axis, and their effects on the fitness landscape.

Finally, in the last few months, the algorithm has been adapted to invert for gravity data available for the Mayon volcano in the Philippines, in association with several colleagues from Europe. We were successful in inverting for the source volume, location, mass and depth below that active stratovolcano, and presented our results at IUGG in England, July 1999.

B. PERSONAL INFORMATION.

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C. PUBLICATIONS ASSOCIATED WITH THIS RESEARCH.

Tiampo, K.F., Hofton, M., Rundle, J.B., and Minster, J.B., 1996. Inversion for the volcanic source at Long Valley, California,using a genetic algorithm technique. Eos, Transactions, AGU, v. 77, n. 46, p. 146.

Tiampo, K.F., Rundle, J.B., Hofton, M., Minster, J.B., and Langbein, J.O., 1997. Inversion for the volcanic source at Long Valley, California, using multiple data sources and a genetic algorithm technique. Eos, Transactions, AGU, v. 78, n. 46, p. 776.

Tiampo, K.F., Rundle, J.B., Fernandez, J.M., and Langbein, J.O., 1998. Ellipsoidal vs. spherical models for magmatic intrusion sources. Annales Geophysicae, v. 16, pt. I, EGS, p. 191.

Bhattacharyya, J., Sheehan, A.F., Tiampo, K., 1998. Genetic algorithm inversion of regional waveforms for western United States crustal structure. Eos, Transactions, AGU, v. 78, n. 46, p. 493.

Bhattacharyya, J., Sheehan, A.F., Tiampo, K., Rundle, J.B. Using genetic algorithms to model regional waveforms for crustal structure in the western United States. BSSA, v. 89, no. 1, Feb. 1999. Copies enclosed.
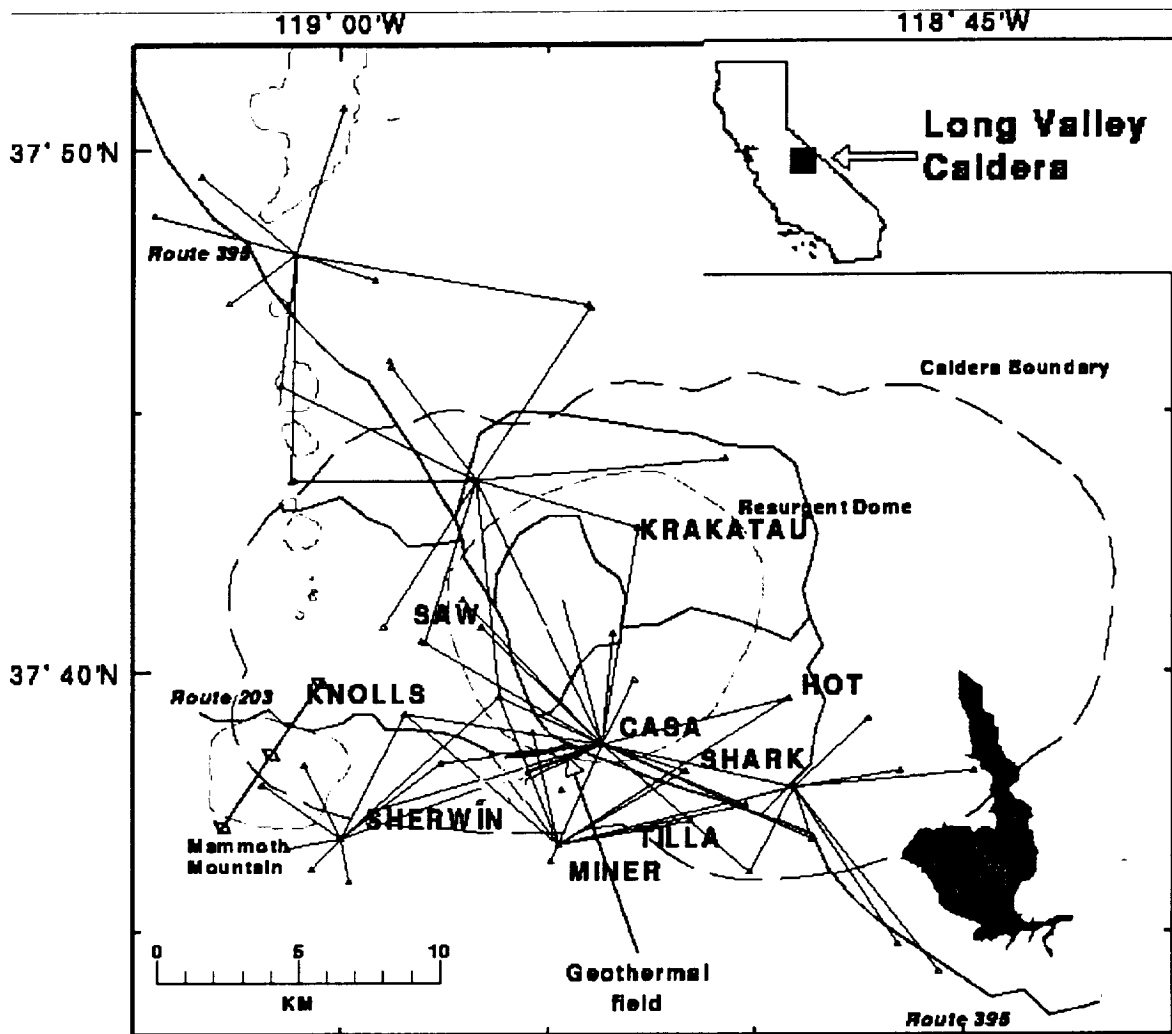
Tiampo, K.F., Rundle, J.B., Fernandez, J.M., and Langbein, J.O.. Spherical and ellipsoidal volcanic sources at Long Valley caldera, California, using a genetic algorithm inversion technique, Journal of Volcanology and Geophysical Research, in review, 1999. Reprints will be forwarded upon publication.

Tiampo, K.F., Rundle, J.B., Fernandez, J.M., and Langbein, J.O. Inversion for multiple volcanic sources using a genetic algorithm technique, IUGG 99, Birmingham, Eng.land.
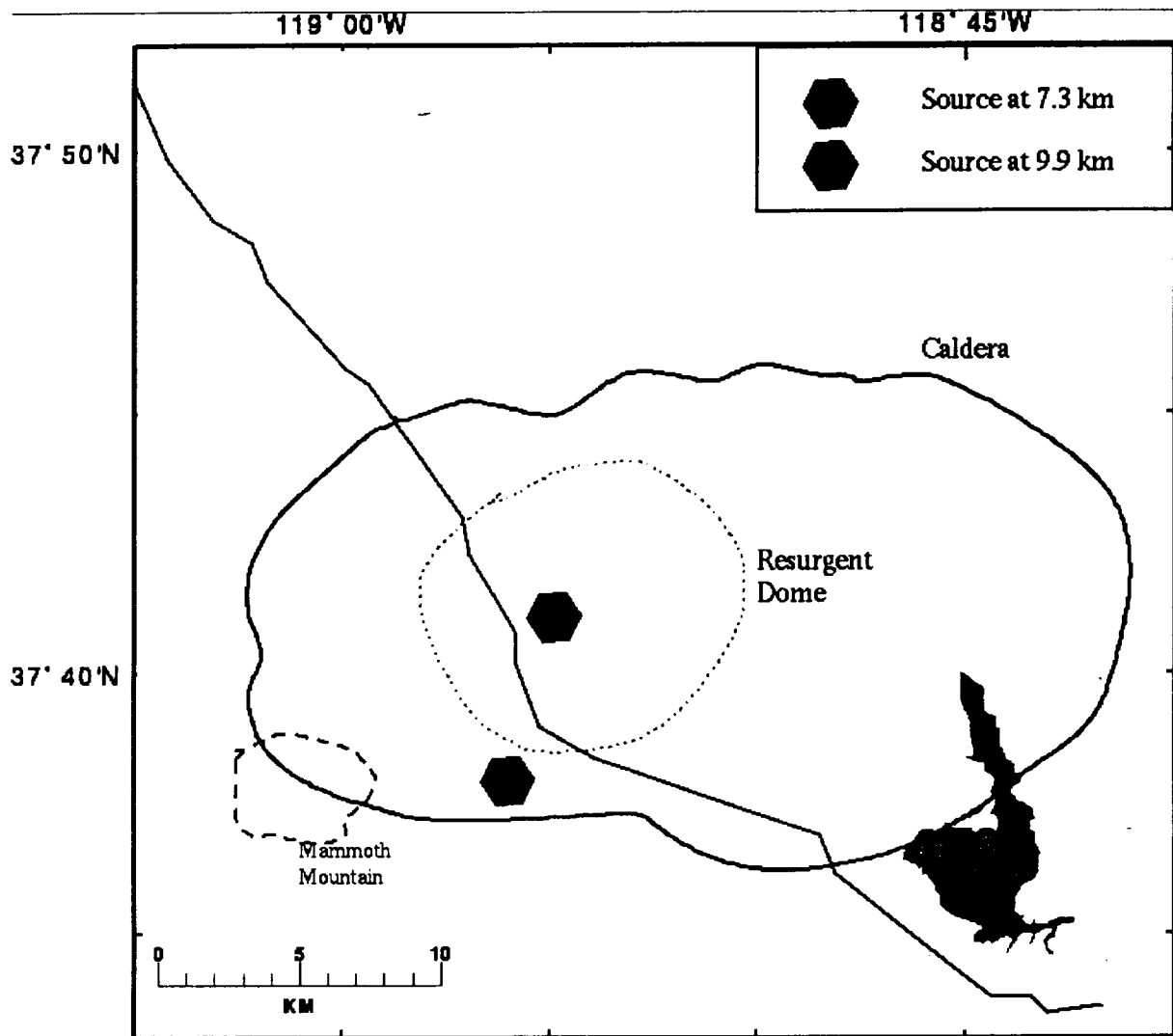
Fernandez, Jose, Kristy F. Tiampo, Gerhard Jentzsch & John B. Rundle, On the interpretation of the microgravity and GPS measurements in Mayon volcano, Philippines, IUGG 99, Birmingham, England.

Fernandez, Jose, Kristy F. Tiampo, Gerhard Jentzsch & John B. Rundle, Microgravity and GPS measurements in Mayon volcano, Philippines, to be submitted to Fall AGU, 1999.
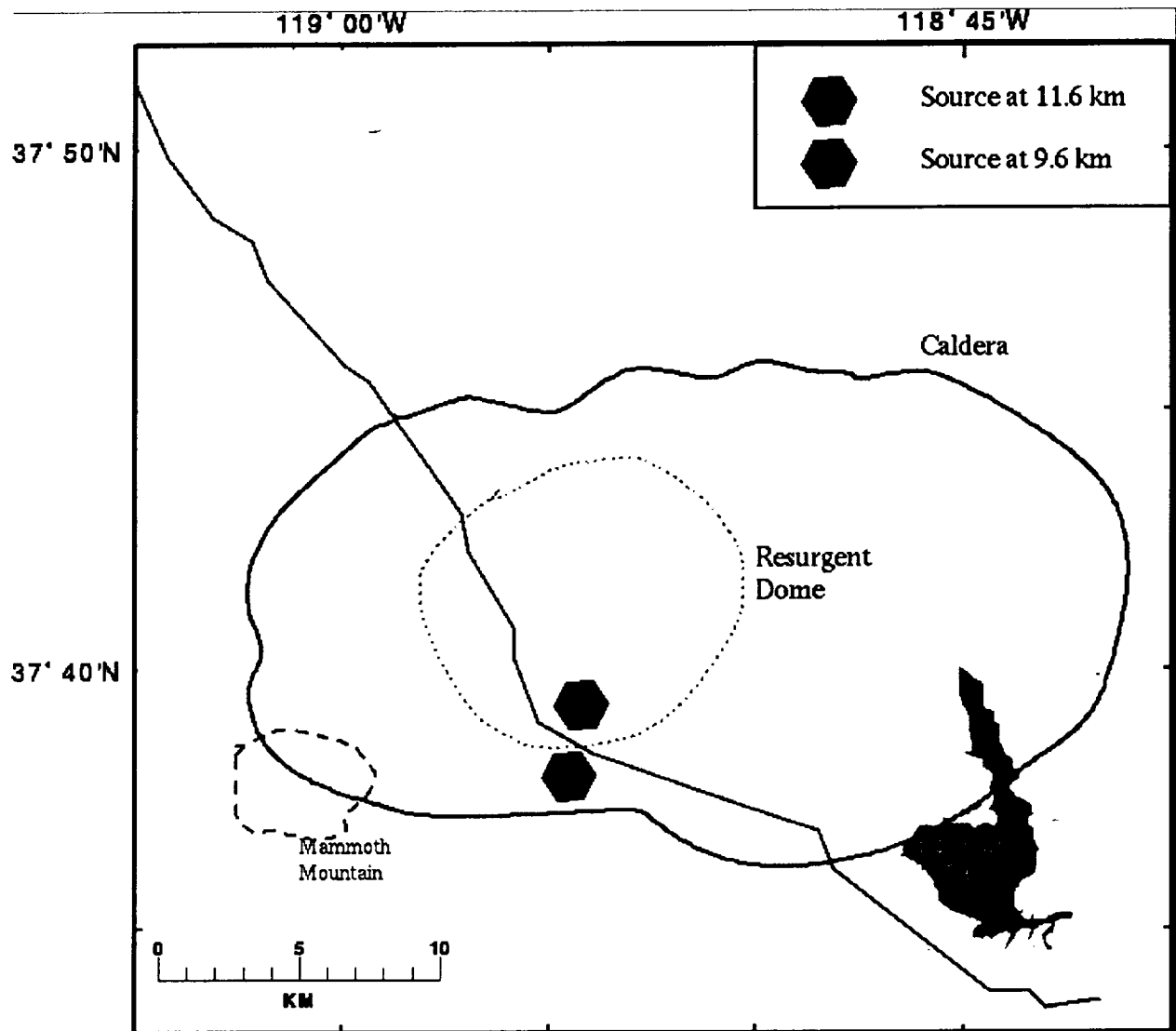
Tiampo, K.F., Fernandez, J., Jentzsch, G. and Rundle, J.B., Inverting for the shallow source at Mayon volcano, Philippines, using microgravity and GPS measurements, to be submitted to JGR or Journal of Volcanology, 1999-2000.
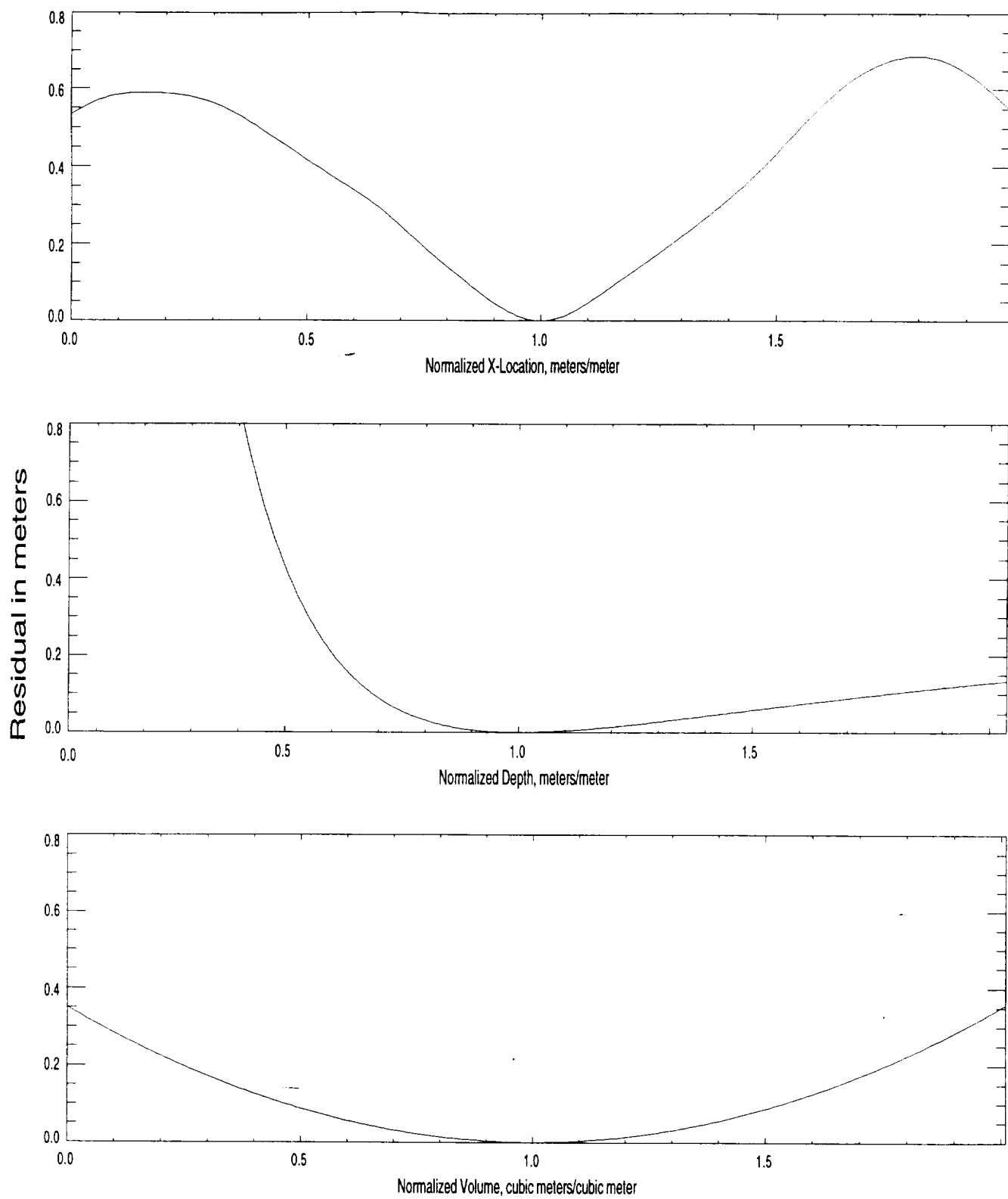
Two-color EDM and leveling lines, Long Valley caldera, California

Map labels:
- 119° 00'W
- 118° 45'W
- 37° 50'N
- 37° 40'N
- Source at 7.3 km
- Source at 9.9 km
- Caldera
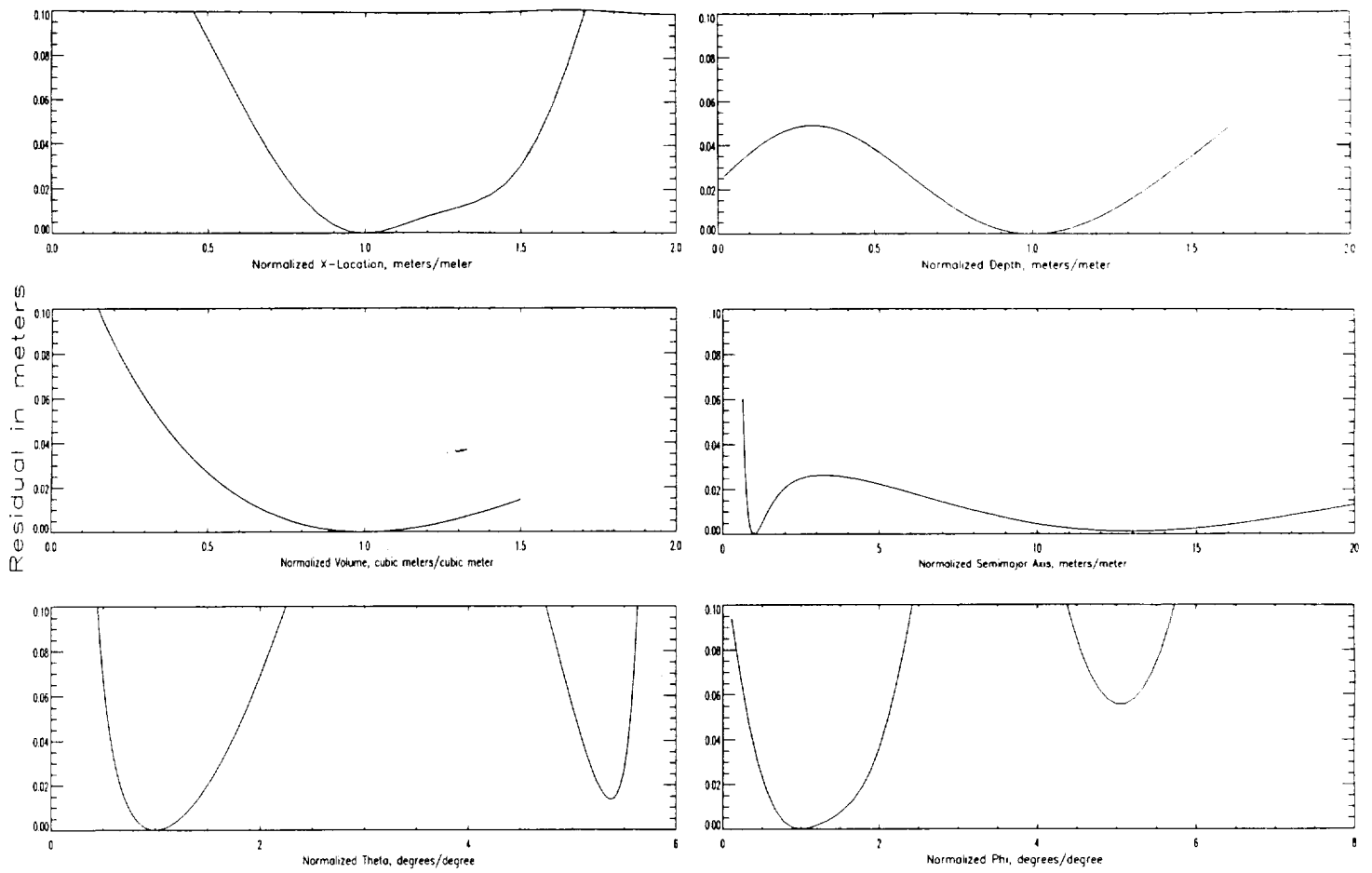- Resurgent Dome
- Mammoth Mountain
- 0   5   10
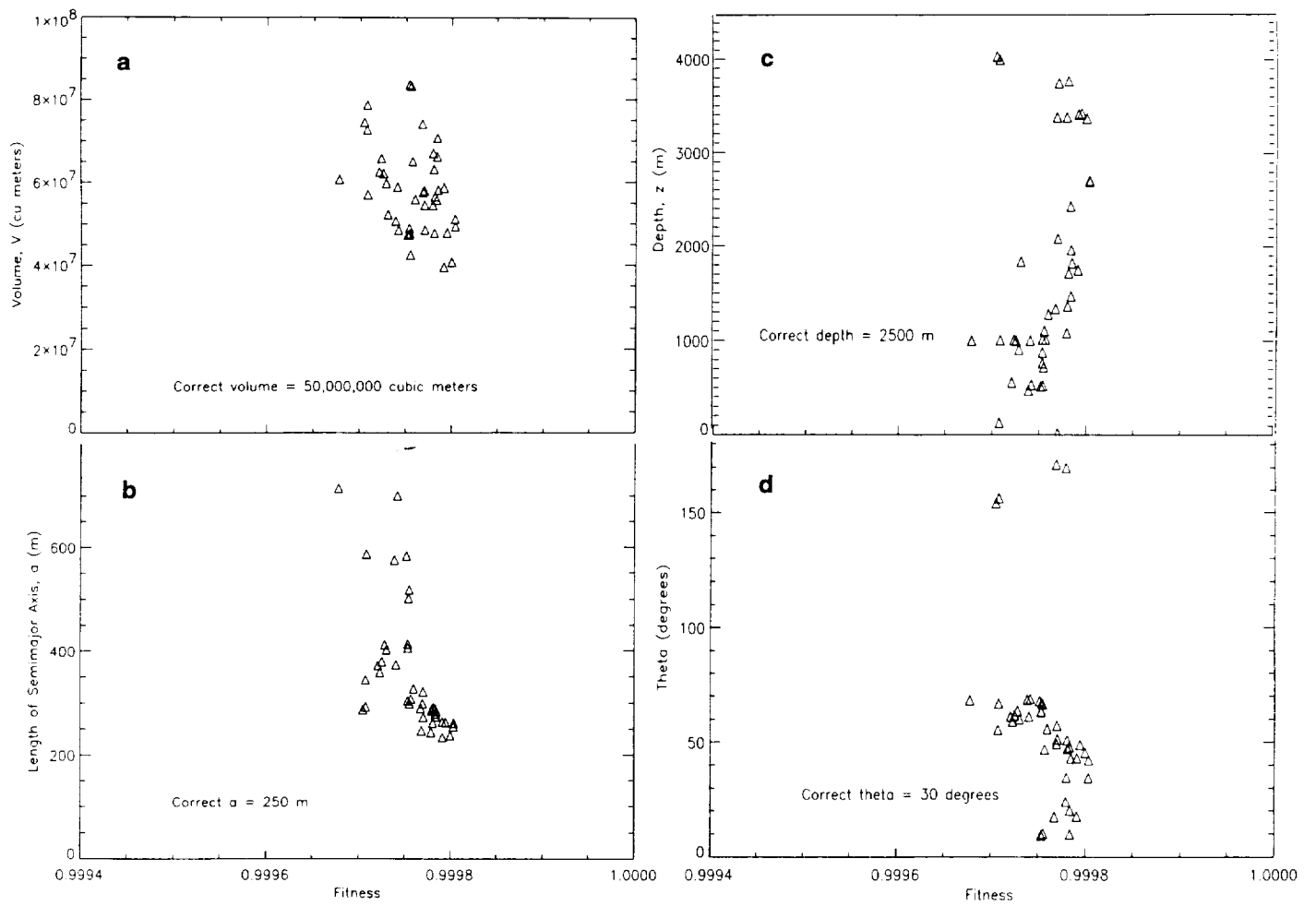- KM

Solution for two sphere inversion, Long Valley caldera, California, 1989-92

Solution for the two ellipsoid inversion, Long Valley Caldera

Sensitivity of fit to Mogi source parameters.

Residual in meters

Normalized X-Location, meters/meter

Normalized Depth, meters/meter

Normalized Volume, cubic meters/cubic meter

Normalized Semimajor Axis, meters/meter

Normalized Theta, degrees/degree

Normalized Phi, degrees/degree

Sensitivity of fit to ellipsoidal source parameters.

Variation in fitness with a. volume, b. length of semimajor axis,
c. depth and d. theta.